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Use of Computer and Mobile Technologies in the Treatment of Depression

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ABSTRACT

Major depression (MDD) is a common and disabling disorder. Research has shown that most people with MDD receive either no treatment or inadequate treatment. Computer and mobile technologies may offer solutions for the delivery of therapies to untreated or inadequately treated individuals with MDD.
The authors review currently available technologies and research aimed at relieving symptoms of MDD. These technologies include computer-assisted cognitive-behavior therapy (CCBT), web-based self-help, Internet self-help support groups, mobile psychotherapeutic interventions (i.e., mobile applications or apps), technology enhanced exercise, and biosensing technology.

INTRODUCTION

Major depression (MDD) has a lifetime prevalence of 14.4% (Kessler, Petukhova, Sampson, Zaslavsky, & Wittchen, 2012) and a negative impact on overall functioning that is often greater than many physical disorders (World Health Organization, 2012). Although several psychological treatments including cognitive-behavior therapy (Dobson, 1989; Hollon, Shelton, & Davis, 1993; Kessler et al., 2012; Butler, Chapman, Forman, & Beck, 2006) and pharmacotherapy (de Maat, Dekker, Schoevers, & de Jonghe, 2007; Thase et al., 1997) have been demonstrated to be effective, most people who have MDD do not receive such treatments (Hirschfield et al., 1997; Davidson & Meltzer-Broady, 1999). For example, the World Health Organization (2011) reported that 76%–85% of those in low/middle income countries and 35%–50% in high income countries receive no mental health treatment. In response to this, technological applications have been suggested as one possible solution to the problem of under-treatment of MDD (Spurgeon & Wright, 2010; Proudfoot, Parker, Pavlovic, Manicavasagar, Adler, & Whitton, 2010).

Ninety-two percent of the U.S. population own cell phones (Anderson, 2015). As of 2015, 68% of cell phone owners were using a smartphone, outnumbering other types of mobile phones, which is a 40% increase since 2011 (Anderson, 2015). Ownership is broadly represented among gender, age, and economic groups and has increased across a wide range of demographic groups, which now include nearly equal proportions of African-American (68%), Hispanic (64%), and Caucasian users (66%) (Anderson, 2015). The majority of these users own a computer (i.e., 73% own a desktop or laptop, and 45% own a tablet computer. (Anderson, 2015). The national average for Internet use is 87% (Duggan, Ellison, Lampe, Lenhart, & Madden, 2015). Zickuhr and Smith (2012) argues that these trends and other technological advancements have spurred increased development of a variety of technology-based tools to deliver or augment treatment of MDD. Moreover, the price of data plan fees (that offer Internet and e-mail capability) has been reduced significantly by cellular service providers, which broadens the population of consumers willing and able to invest in the smartphone concept (Klassen, 2011). These advances prompt us to present the usage of these technologies—and other related technologies—to address the issues of under or inadequate treatment of MDD.

In this review, we examine computer-assisted cognitive-behavior therapy (CCBT), web-based treatments (e.g., Internet support-groups), mobile psychotherapeutic interventions (e.g., mobile apps), technology-enhanced exercise, and biosensing technology. Our search strategy was not to perform an exhaustive search of all technological applications, but rather emphasize known technologies that are readily available to patients or offer promise for treating depressive disorders. General guidelines for inclusion of particular studies in this review were the following: (1) studies that provide feasibility data for promising interventions for issues that are important to depressed patients (e.g., ease of use, symptom reduction, and remote access); (2) studies

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that provided evidenced-based data, especially those with randomized controlled trial designs and (3) studies with rigorous, meta-analytic methods. Other review articles were included if they provided practical information about either the therapeutic use of a technological approach or information on how to access freely available sites to address the clinical problems of depressed patients.

COMPUTER-ASSISTED CBT FOR DEPRESSION

Computer-assisted therapy has been defined as psychotherapy that uses a computer program to deliver a substantial portion of the therapy content or uses a computer program to assist the therapist (Wright, Thase & Beck, 2014a). Efforts to develop and test computer programs for depression treatment began in the 1980s with the work of Selmi, Klein, Greist, and Harris (1982), Selmi, Klein, Greist, Sorrell, and Erdman (1990)), and Colby and Colby (1990), who all introduced software that instructed patients on the basic principles of cognitive-behavior therapy (CBT).

The first multimedia programs for computer-assisted CBT (CCBT) of depression were developed and tested by Wright, Wright, Salmon, et al. (2002) and Proudfoot et al. (2003, 2004). The Proudfoot et al. program *Beating the Blues* was compared to treatment as usual (TAU) in a large sample (n = 274) of primary care patients with mixed depression and anxiety. Patients in both treatments (CCBT or TAU) could receive antidepressants and also had support from the primary care clinicians. The Beating the Blues software uses video simulations and interactive exercises to educate patients and build CBT skills. CCBT patients had lower Beck Depression Inventory-II scores (Beck, Steer, & Brown, 1996) 3 months after treatment (CCBT = 12.1; TAU = 16.4).

Conversely, Gilbody et al. (2015) who conducted an RCT of the cCBT software program Beating the Blues vs. MoodGym, a freely available CBT internet site vs. usual GP care in 691 primary care depressed patients, reported there was no benefit of adding Beating the Blues (n = 210) or the freely available MoodGym (n = 242) to treatment as usual (n = 239). Specifically, at the 4-month follow-up where depression was rated with the PHQ-9, the O.R. was 1.19 (95% CI 0.75–1.88) for Beating the Blues compared to usual care and the O.R. was 0.98 (95% CI 0.62–1.56) for Mood Gym compared to usual care. They also noted a drop-out of 24% by the 4-month follow-up.

Wright et al. (2005) conducted a randomized, controlled trial of CCBT using the *Good Days Ahead* software in patients with MDD. Forty-five drug-free patients with MDD were randomly assigned to CCBT, standard cognitive-behavior therapy (CBT), or a wait list. Nine treatment sessions were used for both treatments, but the clinician contact time in CCBT was reduced by about one half. There were no significant differences found in primary outcome measures between CCBT and CBT, and both forms of CBT were significantly better than the wait list in reducing symptoms of depression. Beck Depression Inventory (BDI-II) change scores from baseline to 8 weeks of treatment were 17.5 for CCBT, 14.7 for standard CBT, and 5.8 for the wait list. Improvement was sustained in both active treatments at the 3- and 6-month follow-up evaluations (Wright et al., 2005). A replication and extension of this study in drug-free patients with MDD found no significant differences between CCBT and a 20-session course of standard CBT despite reducing therapist contact time by about 2/3 in CCBT (Wright, Wright, & Beck, 2014b).

The software for CCBT (Wright et al., 2005; Wright et al., 2002; Wright et al., 2014b) uses multimedia (i.e., video, audio, graphs, and illustrations), self-help exercises, checklists, multiple choice questions, and extensive feedback to engage users and convey basic concepts of CBT. The Good Days Ahead and Beating the Blues programs described above can be delivered on computers in clinical settings or are available in on-line platforms that can be supervised by clinicians.

A review and meta-analysis of computer-assisted therapy that included five studies of CCBT for depression (Andrews, Cuijpers, Craske, McEvoy, & Titov, 2010) found strong evidence for the effectiveness of this approach with an average effect size of 0.78. All of the studies in this meta-analysis were conducted in clinical settings or included therapist support with online delivery. However, effect sizes have been substantially lower for studies that do not include at least a small amount of clinician support (Richards & Richardson, 2012; Thase et al., 2014; Arnberg, Linton, Hultcrantz, Heintz, & Jonsson, 2014).

Research on CCBT for depression has been expanding rapidly. Programs have been produced and tested in many countries including Australia, China the Netherlands, Sweden, the United Kingdom, and the United States (Richards & Richardson, 2012; Thase et al., 2014; Arnberg et al., 2014; Twomey & O, 2016). The overall results of this growing research effort suggest that CCBT (1) is not inferior to standard CBT for depression if clinician support is included in the treatment package, (2) produces significant cost savings, and (3) can improve access to effective psychotherapy. Yet questions remain about the amount and type of therapist support needed (e.g., face-to-face, telephone, e-mail, and telemedicine), optimization and personalization of computer programs used in treatment, predictors of treatment outcome (e.g., patient characteristics that predict favorable or unfavorable response to CCBT), and clinician acceptance of computer technology in the delivery of psychotherapy (Richards & Richardson, 2012; Thase et al., 2014; Arnberg et al., 2014 and Twomey & O, 2016). We conclude that CCBT has substantial potential for enhancing the treatment of depression.

WEB-BASED SELF-HELP FOR DEPRESSION

Although web-based self-help has the potential to reach very large numbers of people with depression, research has found that most people who access self-help CBT sites stay with the program for only brief amounts of time (Spurgeon & Wright, 2010). For example, (Christiansen, Griffiths, Groves, & Korten, 2006), in an analysis of the popular Australian website *Mood Gym*, found that only 138 of 3176 users completed the program. Other researchers have reported about a 1% completion rate for on-line self-help psychotherapy programs with no therapist support (Eysenbach, Powell, Rizo, & Stern, 2004). In contrast, studies of clinician supported CCBT have found much higher adherence. Wright et al. (2002, 2005) observed completion rates of 78% and 87% in two studies of CCBT for depression. Another problem with pure self-help online CBT programs is that they have typically not been as effective in reducing symptoms of depression as clinician supported CCBT (Spek et al., 2007; Spurgeon & Wright, 2010). A meta-analysis by Spek et al. (2007) found relative low effects for online CBT programs that did not use therapist support. However, a meta-analysis by Andrews et al. (2010) found strong effects for this form of computer-assisted therapy with associated with clinician support.

Birney et al. (2016) conducted an RCT on MoodHacker, a self-guided intervention designed to activate CBT skills in working adults with mild to moderate depression as clinician supported CCBT (Spek et al., 2007; Spurgeon & Wright, 2010). The participants of this RCT included 300 employed adults from EAP or Non-EAP organizations. Participants were randomized to MoodHacker (N = 150) or alternative care of links to vetted websites for depression (N = 150). MoodHacker yielded significant effects on depression, work productivity, absence, and workplace distress for those who had access to the EAP but no significant effects for those without access to EAP (Birney et al. 2016). The average time of use was 1.3 h from baseline to 6-week follow-up. The depression effect size (partial eta) was 0.21, p = 0.01, but 0.93 for those with access to EAP, p = 0.004, providing additional evidence that clinician support leads to a more robust clinical effect for Internet-based self-help for depression, especially those with a CBT basis.

Titov (2011) also conducted a review of internet delivered psychological treatments with and without guidance. Low intensity treatment included less than 3 h of therapist time, whereas self-guided treatment involved internet delivered programs for depression with problem-solving or CBT principals without therapist intervention. Low intensity

internet-delivered psychotherapy had similar effect sizes as higher levels of therapist contact (i.e., effect sizes in excess of 1.0). Self-guided treatment, while delivering some benefits to patients who completed, had a low to moderate effect size (0.20 to 0.40) (Titov, 2011). This review indicates that online self-help programs may offer at least a modicum of benefits for some people with depression, especially those who live in areas where qualified therapists are in short supply or prefer to work on their own without seeing a clinician.

Renton et al. (2014) surveyed 32 internet-based programs for depression on 27 websites. Using a 28-point scale, Renton et al. (2014) evaluated the websites for accessibility (i.e., fees, language and registration requirements), usability (i.e., statistics, approach, mode of delivery), tools (i.e., additional features, available worksheets and assessments), support (i.e., clinician or peer support, crisis links), and evidence (i.e., were randomized clinical trials done). The findings reported by Renton et al. (2014) varied widely. For example, only 12% had published evidence of efficacy and treatment for depression. The majority had no peer or clinician support but were free with unrestricted registration. Most were from Australia, the United Kingdom, or the United States. Cognitive Behavior Therapy was the largest therapeutic approach with multi-form delivery. Adult audiences were targeted most frequently (N = 19). Average scores for sites that were derived from evidence-based practice was 80%, while average scores with a non-evidence base was 73%. Renton et al. (2014) comment on the many positive aspects of these websites (i.e., available 24 h/day, accessible regardless of insurance coverage) but encourage a careful inspection of those elements considered as well as whether or not there is an evidence-base and empirical evidence before selecting a specific web-based program.

Despite the identified variation in websites for depression, in a survey of views of self-help websites (i.e. cCbt and informational websites) in a workplace context, Schneider, Foroushani, Grime, and Thornicroft (2014) found that 60% of participants held online treatment to be at least as acceptable as seeing a professional for mental health issues. However, Schneider, Foroushani, Grime, and Thornicroft (2014) report that (1) 45% of the participants dropped out by 6 weeks and (2) many reported barriers to use, such as imperfections with technical aspects of the website and barriers with dyslexia. Schneider et al., (2014) conclude that self-selection of the participants was a significant limitation of the findings and the websites are not for everyone and are best viewed as an adjunct to treatment. Newman, Szkodny, Llera, and Przeworski, (2011) report similar findings in their review of technology-assisted self-help for anxiety and depression (i.e., that therapist assisted treatment was optimal for clinical depression and technology-based treatment alone may be efficacious for subthreshold mood disorders).

A principal example of online self-help programs is “Mood Gym” (http://moodgym.anu.edu.au) which reported 817,284 “hits” in the first month of operation (Christiansen, Griffiths, & Korten, 2002). “Mood Gym” provides five CBT training modules, a personal work log containing assessments, an interactive game, and a feedback form. Overcoming Depression (Williams & Whitfield, 2001) is another self-help program that is available on the Internet. It provides structured workbooks for CBT of depression. The program specifically targets change in unhelpful thinking, poor problem solving, lack of assertiveness skills, reduced activity levels, sleep difficulties, and use of antidepressants. Six workbooks are available on the web at www.calipso.co.uk.

INTERNET SELF-HELP SUPPORT GROUPS

A variety of self-help support groups are available on the Internet, which include bulletin boards, chat rooms, news and discussion groups, and electronic mail lists in which each individual's message is copied and e-mailed to all subscribers. These support groups emphasize shared experiences, provide practical information, stimulate hope, and offer 24-h availability as an adjunct to traditional treatment (Castelnuovo, Gaggioli, Mantovani, & Riva, 2003). Depression tops the list of internet support groups sought on the America Self-Help Clearinghouse (Lamberg, 2003). Sites to obtain information on support groups include the following: www.irchelp.com; www.mirc.com; www.walkers.org; www.selfhelpgroups.org; www.dbsalliance.org; www.nami.org; www.drada.org and alt.support.depression. The National Institute of Mental Health itself receives 77 million hits each month (Taylor & Luce, 2003). Walkers in Darkness, a non-profit group for mood disorders, with 500,000 visits annually, has six current e-mail lists, 18 web-based forums, and 2400 regular users (Lamberg, 2003). The Depression and Bipolar Support Alliance has two weekly Internet support groups for individuals and families of those with mood disorders. Alt.support.depression is a discussion group read by 20,000 people. NAMI also has mental health Internet support groups. DRADA (Depression and Related Affective Disorders Association) is a peer-support program that links individuals who want to write or e-mail (Lamberg, 2003).

In the first prospective cohort study of internet support groups, researchers from Johns Hopkins University recruited 103 subjects from the Walkers in Darkness website and followed them for 11 year. More frequent users were more likely (42.9% vs. 20.7%) to have their depression resolve compared to the less frequent users when age, gender, and baseline CES-D score were controlled (Houston, Cooper, & Ford, 2002). Individuals in this cohort study (N = 101) reported lower emotional support in 8 of the 9 support variables ($p < 0.01$) compared to a conventional treatment group from the Quality Improvement for Depression Study (N = 1424). Houston et al. (2002) concluded that the modality is associated with improvements in depression in users who were socially isolated.

The overall results of studies of the impact of peer-to-peer, online support groups have not found consistent positive effects. In a literature review of published studies (Eysenbach et al., 2004), there was no robust evidence of health benefits from peer-to-peer electronic support groups. Twelve of the studies were with depressed subjects. Only three of the depression studies produced a significant result. However, the authors conclude that negative findings could relate to study design because there were many underpowered or poorly designed exploratory studies.

MOBILE PSYCHOTHERAPEUTIC INTERVENTIONS

An early review of 27 intervention studies showed patient acceptance and treatment efficacy for patient data-collection in real-time (Heron & Smyth, 2010). Since that time, numerous mobile apps became available through android and apple marketplaces to assist with real-time data collection. Shen et al. (2015) recently identified 243 apps for depression (Shen et al., 2015). An assessment of those apps available concluded: 1) 210 failed to mention depression in the app title or description; 2) 82 involved a therapeutic treatment; 3) 78 were comprised of psychoeducation for depression; 4) 41 included medical assessment for depression; 5) 20 encompassed symptom management and 6) 4 entailed supportive service. The majority failed to identify an organizational affiliation or source of content and had an average rating of 3.5 out of five stars. Notwithstanding, the lack of empirical data documenting likely uptake, best strategies for engagement, efficacy, or effectiveness of mHealth initiatives is unmistakable (Bakker, Kazantzis, Rickwood, & Rickard, 2016; Tomlinson, Rotheram-Borus, Swartz, & Tsai, 2013). In fact, these authors go on to stress that no mHealth intervention has met rigorous standards and rarely do developers conduct or publish empirical validation of their apps. Unfortunately, those studies that do report the results of their apps in the literature are often plagued by small sample sizes (Donker et al., 2013).

An example of popular depression apps without empirical data include “CBT Thought Diary,” which identifies and challenges thinking trends using CBT techniques and behavioral experiments; “CBT referee,”

which prompts users to write down thoughts as they arise to look back and reflect; "eCBT," which records automatic thoughts to create a log and challenge thinking; "MoodKit," aimed to disseminate CBT methods and related resources/organizations; as well as "iCBT," a manager of reactions and emotions. See Bakker et al., 2016 for a comprehensive list of IOS mental health apps and Luxton, McCann, Bush, Mishkind, & Reger, 2011 for a comprehensive list of behavioral apps in the IOS, Android, and Blackberry platforms. Most can be downloaded for a minimal cost (about $5.00).

Despite the lack of empirical evidence, mobile interventions are, nonetheless, well accepted by end users for physical and mental health treatment (Aguilera & Muench, 2012). In a survey of 525 respondents, 76% said they were interested in using apps for self-management and self-monitoring of mental health (Proudfoot et al., 2010). They have been seen as a cost-effective method to provide mental health care for those unable to access or afford traditional therapy (Price et al., 2014). Additionally, Price et al. have identified mHealth as a vehicle to reduce the likelihood of relapse by promoting adaptive skills.

The appealing features of smartphones for mental health treatment are expanding with technology advancements. They include larger screens, easier data input, and lighter weight to optimize user-friendliness. Specific to psychotherapy, the characteristics of smartphones deliver accurate monitoring back to therapists without requiring pen and paper or relying on memory. Boschen and Casey (2008) posit that the smartphone may be an "ideal therapy augmentation device" for Cognitive Behavior Therapy (CBT) because they have a clearly readable screen, the ability to remind patients through audio cues, and the ability for easy information gathering and monitoring. This method of real-time assessment has the potential to supply information "about individual differences, about particular episodes or situations, about the unfolding of processes over time, and about the interactions among these factors (ecological momentary assessment: EMA)" (Shiffman, Stone, & Hufford, 2008; Wichers et al., 2011). The potential to predict depression is made possible by the moment to moment variation in mood states when paired with real-time data analysis (Sandstrom, Lathia, Mascolo, & Rentfrow, 2016). Through machine learning, an analytic strategy to examine patterns of behavior and predict behavior, associations too complex to scrutinize by hand can be examined by the many thousands of data points obtained through smartphone technology. For example, EmotionSense, a system to pair EMA data and sensor data, was able to use this analytic strategy to relate self-reported mood to sensed physical activity (Sandstrom et al., 2016). Torous et al. (2015), and Marzano et al. (2015) also advance in what way active, passive, social, and behavioral data (high velocity data), collected in real time through smartphones, may be used to identify hidden states such as suicidal risk using advanced analytic methods such as Markov modeling (Torous, Staples, & Onnela, 2015). Specifically, the rich data such as meaning, context, functions of people's emotional states, activities, and behaviors, collected on smartphones, may assist in the identification of how symptoms may fluctuate in time, space, and across social situations (Marzano et al., 2015).

Morris et al. (2010) reported a trial of a phone application "Mobile Therapy," with touch screen scales for prompted mood exercises, that they tested on 10 adults to determine the potential for in-the-moment support. (Morris et al., 2010). The field pilot study lasted one month and included weekly open-ended interviews. The study concluded that participants were able to grasp the concept of the application quickly, and the application was considered "non-stigmatizing" (Morris et al., 2010).

The feasibility of mobile phones as a supportive device for therapeutic services with adolescents was examined in a non-clinical sample of adolescents. Specifically, a mobile phone was modified for mood charting (Matthews, Doherty, Sharry, & Fitzpatrick, 2010). A pilot study of the mobile mood diary was installed on the phones of a subset of 73 self-selecting students whose ages ranged from 13 to 17 years. Fifty-two of the students received paper and pencil diaries and 21 received the mobile mood diary. None of the adolescents had apparent mental health problems. They were asked to record their mood for two weeks. There was a significant difference between the mobile mood diary group and the paper and pencil group ($t = -2.324$; $p < 0.027$). Subjects reported ease of use and a preference for using the mobile approach (88.7% preferred mobile compared to 11.3% who preferred paper and pencil). This exploratory study demonstrated the feasibility of collecting mood data in a non-clinical adolescent sample. Future studies will be required to demonstrate the usefulness in depressed adolescents.

A recent RCT of mobile app/IPad vs the computer with a program named "Get Happy" was conducted in 35 persons with mild to moderate depression (Watts et al., 2013). The sample was randomly assigned to a CBT-based program (i.e., six lessons that were clinician assisted until lesson two) to either the mobile app/IPad delivery or delivery by personal computer. At 3-month follow-up, both groups had significant benefits in depression reduction as measured by the PHQ-9, BDI-II, and K-10, a measure of distress. There were no differences between the groups and large within group effect sizes of >0.8 (Watts et al., 2013).

Despite these favorable examples, there may be obstacles or disadvantages associated with the therapeutic use of mobile devices. Cost is a consideration. A smartphone, depending upon the brand and model, may be quadruple the price of a standard model cellular phone. It remains to be determined whether mobile applications will be found to be a cost-effective method of psychiatric treatment. If the patient selects a total substitution of the mobile therapeutic application instead of standard in-person treatment, the consequent reduction of in-person therapeutic contact could adversely affect clinical outcome. Given this concern, Marzano et al. (2015) identifies a priority for future research to be the examination of which patients may benefit from stand-alone apps vs. when used as an adjunct.

Also, typical complications of technology should be anticipated when incorporating mobile phones into therapy (e.g., technology malfunctions, potentials for confidentiality breaches, etc.). See Aguilera and Muench (2012) for a thorough discussion of ethical and HIPAA concerns with mobile apps in a therapeutic context.

BIOSENSING

Recall data, using hard-copy surveys, is subject to biases related to memory and current mood (Rabbi, Ali, Choudhury, & Berke, 2011). With health care able to incorporate web-based or mobile phone-based surveys, inaccessible populations can be reached, time and cost constraints are lifted, information can be gathered closer to real time, assessment questions can be tailored to patient responses, and patients can record responses as individually preferred (i.e. written, spoken, photographed, or videotaped) (Lathia et al., 2013; Rabbi et al., 2011; Marzano et al., 2015). The high level of interactivity prompted by digital resources can positively change behaviors associated with depression, including substance use, diet, sexual behavior, and stress (Lathia et al., 2013). However, the burden on the patient is still present, and continuous data collection remains out of reach (Lathia et al., 2013; Rabbi et al., 2011).

Beyond the capabilities of self-report and recall data in mobile phone applications to measure health outcomes over time, recent attention has been directed towards using biosensors to collect more accurate information (Rabbi et al., 2011). For example, using a mobile sensing program called Mobilyze!, a 2011 study produced accuracy rates of 60–91% (Burns et al., 2011). Likewise, Lathia et al. (2013) reported upwards of 70–90% accuracy for their sensor system called EmotionSense. Being that the majority of smartphone users habitually travel with their phones throughout the day, consumers are more likely to forget the data collection process is even occurring, thereby limiting bias (Marzano et al., 2015; Lathia et al., 2013). By using biosensors to automatically generate information, such as physical activity, energy expenditure, and acoustical speech properties, consumers will be less

burdened with time-consuming reporting methods, making longitudinal data collection more reasonable (Ben-Zeev, Scherer, Wang, Xie, & Campbell, 2015; Rabbi et al., 2011; Berke, Choudhury, Ali, & Rabbi, 2011). Using smartphone sensors over a 10-week period, a study conducted by Dartmouth College found significant relationships between Patient Health Questionnaire (PHQ-9) depression (Kroenke & Spitzer, 2002) and speech duration ($p = 0.048$), geospatial activity ($p = 0.022$), and sleep duration ($p = 0.028$) (Ben-Zeev et al., 2015).

Evidence has shown that certain biosensing measurements can also demonstrate that social activity correlates with depressive symptoms (Rabbi et al., 2011; Berke et al., 2011). Rabbi et al. (2011) and Berke et al. (2011). These researchers all found a negative correlation between sensed human speech in conversation and Center for Epidemiological Studies - Depression (CES-D) scores (i.e., as conversational speech increased, depressive symptoms decreased). Berke et al. (2011) demonstrated a statistically significant association between speech and CES-D scores when adjusted for age and sex ($p = 0.04$). Additionally, Rabbi et al. (2011) demonstrated improved friendship according to the Friendship Scale ($R = 0.96$, $p = 0.002$) (Sharabany, 1994). Studies have shown that by using continuous biosensing techniques, consumers and their health care providers can see accurate trends and, through individualized interventions based off of exactly when and where a symptom is triggered, improved depressive symptoms (Rabbi et al., 2011; Berke et al., 2011; Lathia et al., 2013; Marzano et al., 2015). For example, Mobilyze! demonstrated a statistically significant decrease in PHQ-9 scores ($p < 0.001$) and decrease in study participants who met criteria for major depressive disorder ($p = 0.03$) (Burns et al., 2011). By having real-time data that assesses depressive symptoms, smartphone sensing apps can be incorporated into clinical care as warning systems for suicide risk (Marzano et al., 2015).

Smartphones possess multiple features that inherently lend themselves to biosensing — barometers, accelerometers, global positioning systems (GPS), compass, microphone, voice and image processing, screen proximity sensor, call use, ambient light sensors, noise sensors, temperature/humidity sensors, eye tracking, Wi-Fi, Bluetooth, the Global System for Mobile Communications (GSM), and near field communication (NFC) (Clough & Casey, 2015; Wahle, Kowatsch, & Weidt, 2015; Burns et al., 2011; Lathia et al., 2013; Amichai-Hamburger, Klomek, Friedman, Zuckerman, & Shani-Sherman, 2014). Physiological indicators have even been investigated in clothing-embedded sensors to track respirations, heart rate, and skin responses (Amichai-Hamburger et al., 2014; Wang & Alexander, 2016). Biosensing offers the ability to reach an immense volume of people, including individuals with impaired communication and the growing geriatric population, through automated monitoring which could lead to more widespread achievement of early diagnosis and intervention and ameliorate rising medical costs of acute or ineffective treatment (Marzano et al., 2015; Berke et al., 2011; Burns et al., 2011). By combining high-level interactivity and real-time data collection, clinicians and consumers can identify personalized relapse cues, facilitating illness prevention. Future research is needed to identify candidates for stand-alone versus adjunctive use of biosensing mental health apps, features that should be automated versus interactive, and when and how feedback should be given to app consumers (Marzano et al., 2015). Investigation is also needed to address user behavior generalization difficulties, privacy and data storage capacity concerns, battery drainage, and connectivity issues seen in biosensing apps in order to fully realize its potential (Lathia et al., 2013).

TECHNOLOGY ENHANCED EXERCISE

Exercise has such profound pharmacological and physiological effects throughout the body that it should be considered a drug therapy (Howland, 2015). Exercise has documented benefits for preventing or treating cardiovascular, metabolic, and other medical conditions or their sequelae, and these conditions are commonly associated with depression. Based on the known physiological effects of exercise, it can potentially alleviate adverse effects associated with drug therapies, including insomnia, sedation, sexual dysfunction, cognitive impairment, weight gain, and metabolic effects. Observational and intervention studies have described an inverse association between physical activity and the likelihood of having or developing depressive symptoms, and a number of systematic reviews have evaluated controlled trials investigating the efficacy of various types of exercise as a treatment for depression (Howland, 2010). These reports show that exercise leads to a greater reduction in depressive symptoms compared to no treatment and that exercise may have antidepressant benefits comparable to psychotherapy or medication.

These studies do not necessarily evaluate depression specifically as a diagnosis or a disorder (e.g., major depression according to current criteria). Many studies have evaluated symptoms of depression or measures of psychological well-being in mixed patient populations, or have focused on less severe, non-chronic, depressed patient populations. Seemingly minor forms of depression are often associated with medical and psychiatric comorbidity (Howland et al., 2008), which would make these types of ideal candidates for exercise.

An important clinical issue is what types, frequencies, intensities, and duration of exercise are clinically effective. A recent review suggested that three 30-minute sessions per week of moderately intense aerobic exercise (60%–80% of maximum heart rate) for at least eight weeks is effective for treating depression (Perraton, Kumar, & Machotka, 2010). There is a need to develop similar evidence-based guidelines for resistance training and other types of structured exercise or leisure time physical activities, which may be effective for treating depression or reducing depressive symptoms (Teychenne, Ball, & Salmon, 2008).

The effectiveness of exercise depends on the willingness and ability of depressed patients to adopt and maintain physical activities. Interactive internet-based programs are useful for promoting physical activities (Marcus, Ciccolo, & Sciamanna, 2009; Van Den Berg, Schoones, & Vliet Vlieland, 2007). These sites address exercise and depression, administer depression and physical self-report assessments, suggest or develop individualized exercise programs, provide a forum for online social support and guidance, encourage goal-setting, promote self-monitoring, and give feedback about progress.

The type, intensity, frequency, and duration of exercise activities are relevant to their effectiveness in treating depression (Perraton et al., 2010). Because these variables are measureable, mobile technologies can be used to record and monitor the type, intensity, frequency, and duration of exercise as a means to motivate users and enhance the potential effectiveness of exercise for treating depression. Smartphones can be used to collect and monitor data on physical activities as well as depression symptom scores, but physical activity can now be objectively monitored through the use of devices worn on the body.

Pedometers count and monitor the number of steps taken throughout the day through such activities as walking, jogging, and running. Controlled studies have shown that pedometer-based walking is associated with increased physical activity, decreased weight or body mass index, and decreased blood pressure (Bravata et al., 2007; Kang, Marshall, Barreira, & Lee, 2009; Richardson et al., 2008). Thresholds for health benefits from walking have been established (Tudor-Locke et al., 2011).

Accelerometers (such as the ActiGraph) record body acceleration minute by minute in three dimensions, providing a more dynamic measure of body movement patterns, frequency, duration, and intensity than just counting steps. The use of accelerometer data provides a more accurate measure of actual physical activity than does self-report data (Troiano et al., 2008). Accelerometer data also can distinguish levels of physical activity from sedentary behavior (Brocklebank, Falconer, Page, Perry, & Cooper, 2015), and this type of data has been shown to be associated with adverse cardiometabolic risk factors (Gorman et al., 2013).

Wearable activity trackers (such as Fitbit or Jawbone) can track steps, distance, physical activity, energy expenditure, and sleep

patterns. Studies have found that these devices have a high level of validity for tracking steps, fewer studies demonstrating validity for distance and physical activity, and a lower level of validity for estimating energy expenditure and sleep (Evenson, Goto, & Furberg, 2015).

Heart rate is one of best indicators of exercise intensity, and a wearable monitor can be used to accurately measure heart rate during various types of physical activity. Using heart rate monitoring in conjunction with an accelerometer can improve the accuracy of estimates of physical activity and energy expenditure (Barreira, Kang, Caputo, Farley, & Renfrow, 2009; Strath, Brage, & Ekelund, 2005), including in adults (Crouter, Churilla, & Bassett, 2008) and in children and adolescents (Zakeri, Adolph, Puyau, Vohra, & Butte, 2008).

Global positioning system (GPS) data can accurately track specific activities according to altitude, distance, time, and average velocity (Schutz & Herren, 2000). Wearable GPS devices (Garmin) are available that can be used during walking, running, or cycling. Devices that combine GPS, accelerometer, and/or heart rate data provide a more comprehensive ability to assess and monitor physical activity intensity (Ermes, Pärkkä, Mäntyjärvi, & Korhonen, 2008; Rodriguez, Brown, & Troped, 2005; Troped et al., 2008).

More recently, the use of interactive video games (referred to as exergaming) has become a popular strategy for combining entertaining and engaging video games with physical activities, such as dancing, biking, boxing, tennis, and other "virtual" sports. Examples include Wii Fit and Kinect. A review of 27 studies found a strong correlation between exergaming and increased energy expenditure to a level of moderate intensity (Sween et al., 2014).

Wearable devices, then, can be used to measure quantitatively the amount and intensity of different types of exercise activities, which can be used as part of an individualized exercise-treatment program for depression (Burns et al., 2011).

SUMMARY

Technological interventions to enhance the treatment of depression include a broad range such as the use of everyday objects such as cell phones to address symptoms and barriers of treatments for depression to various internet and biosensing resources. Technology offers solutions to act on the biologic, psychological, educational, and environmental spheres affected by depression. As can be seen from the research presented, much of the technology is in the feasibility/pilot phase, yet, the findings offer promise for improving behavioral health practice.

Addressing the barrier of time and availability, technology has made treatment access available in remote under-served areas and on a 24/7 basis for those whose schedule precludes seeking depression therapies at regular business hours. Patients report a high degree of satisfaction with alternate approaches. Problems with viruses and online privacy are also potential road blocks to the use of technology in treatment of depression. Virus protection and encryption may raise the level of security but are not full-proof.

Creative uses of computer-assisted CBT have also been well-accepted by patients and have been functional adjuncts to treatment in the United Kingdom (Beating the Blues) and the US (Good Days Ahead). The CCBT programs have demonstrated clinical outcomes that are equivalent to standard CBT and in some areas, better. The adjunctive model of CCBT appears to be the most promising and cost-effective, given findings that outcomes are enhanced when therapist support is available (Spek et al., 2007).

The internet allows an expansion of traditional psycho-educational approaches by offering many reliable sites for information about depression and groups for support. They may offer ways to combat social isolation but should be used with the understanding that best results occur when they are adjunctive to reputable treatment. Peer-to-peer support groups should be considered with the recognition that results have not demonstrated the same type of efficacy as those with a professional leader. Despite this cautionary note, the internet can provide a wealth of information and social resources for those with depression and can fill in gaps for many without effective resources.

Technological applications for depression have been expanded through the use of mobile smartphones which allow "on the go" functions that benefit mood disorders. They include automated reminders, ability to monitor, consistent access to therapeutic components, and assistance with depression-related deficits via the organization offered through lists, note-taking, and exercise support, etc.

Clinicians are just starting to draw from technological "tool boxes" to enrich their work in treating depression. Currently, a number of valuable options are available including psychoeducation through the internet, computer-assisted CBT, exercise monitoring, and internet based support groups. We predict that as clinicians learn more about these approaches, and patients become more sophisticated in the search for solutions to relieve their symptoms, technological advances will have increased influence on the treatment of depression.

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